Upgraded Worldwide Ocean Optics Database

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LONG-TERM GOALS

The long-term objective is to provide a comprehensive worldwide optics database that includes data on a broad range of important optical properties, including diffuse attenuation, beam attenuation, and scattering. Data from ONR-funded bio-optical cruises are given priority for loading into the database, but data from other scientific programs (NASA, NODC, NSF) and from other countries will also be routinely added to the Worldwide Ocean Optics Database (WOOD)[1]. The database shall be easy to use, Internet accessible, and frequently updated with data from recent at-sea measurements. The database shall be capable of supporting a wide range of applications, such as environmental assessments, sea test planning, and Navy applications. The database shall include derived optical parameters so that if measured data are not available, the user can obtain values computed from empirical algorithms (e.g., beam attenuation estimated from diffuse attenuation and backscatter data). Uncertainty estimates will also be provided for the computed results.

OBJECTIVES

A main analysis objective has been to determine whether one can use radiative transfer theory to accurately generate "Derived Parameters." Another objective is to provide data and algorithms having direct relevance to US Navy applications and needs. The US Navy has a special interest in locations such as the East China Sea, Yellow Sea, Gulf of Oman, and the Persian Gulf. Therefore, we will give special attention to testing the algorithms/software using data from such locations. Attention will also be given to testing the methodology within nepheloid layers (sediment-laden bottom waters) because of the US Navy's plans to use optical sensors to detect bottom mines. An on-going objective is to acquire and add new optics data to WOOD, and therefore a related objective is to develop more automated procedures for ingesting new datasets, especially from high-density measurement systems like a glider or SeaSoar system[2].

APPROACH

Multi-wavelength AC-9 and backscattering data are being used to test Kiefer's Hydro-Optical Analysis System (HOPAS[3]). HOPAS uses a modified version of HydroLight to "invert" easily measured optical data (such as Apparent Optical Properties (AOPs), irradiance, and radiance), to obtain estimates of Inherent Optical Properties (IOPs). Data from a variety of seasons and locations are being tested in order to determine seasonal and geographic dependencies. Our focus is on the empirical relationships among the IOPs known as absorption (**a**), scattering (**b**), and total beam attenuation (**c**), and on the relationship of the various IOPs to the diffuse attenuation coefficient (K). The accuracy of

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each algorithm will be assessed in terms of absolute errors, such as the root-mean-square difference between measured and calculated values, and in relative terms such as the median absolute *percent* error. The absolute error is used to treat high or low values equally. The relative (percentage) error is used to account for the great variability in attenuation coefficient values as a function of depth.

In performing this algorithm work, the best available data are being used, but some of these data are DoD-restricted and therefore cannot be posted on the WOOD public website. For example, we will be using high quality military survey data from the Middle East and the Yellow Sea. We are presently testing HOPAS with Sea of Japan data provided by Dr. Greg Mitchell (Scripps) acquired as part of a major ONR field program conducted there in March/April 2001.

WORK COMPLETED

The main thrusts of our work this past year involved 1) preparing/loading new data into WOOD, 2) developing data thinning algorithms to be applied to over-sampled data, and 3) investigating automated software that uses radiative transfer theory to compute derived optical properties. We also added several new features to the WOOD website including a GUI interface to produce color-coded "depth slice" plots of optical parameters (and Secchi depths) on a geo-map.

New Data Added to WOOD: With respect to the preparation and loading of new datasets, Table 1 summarizes what has been accomplished since September 2005. In addition, several large collections of datasets are nearly ready to be loaded, such as the Mediterranean Sea Atlas 2002 data archive[4] and the WHOI Arabian Sea SeaSoar data sets (four cruises)[5].

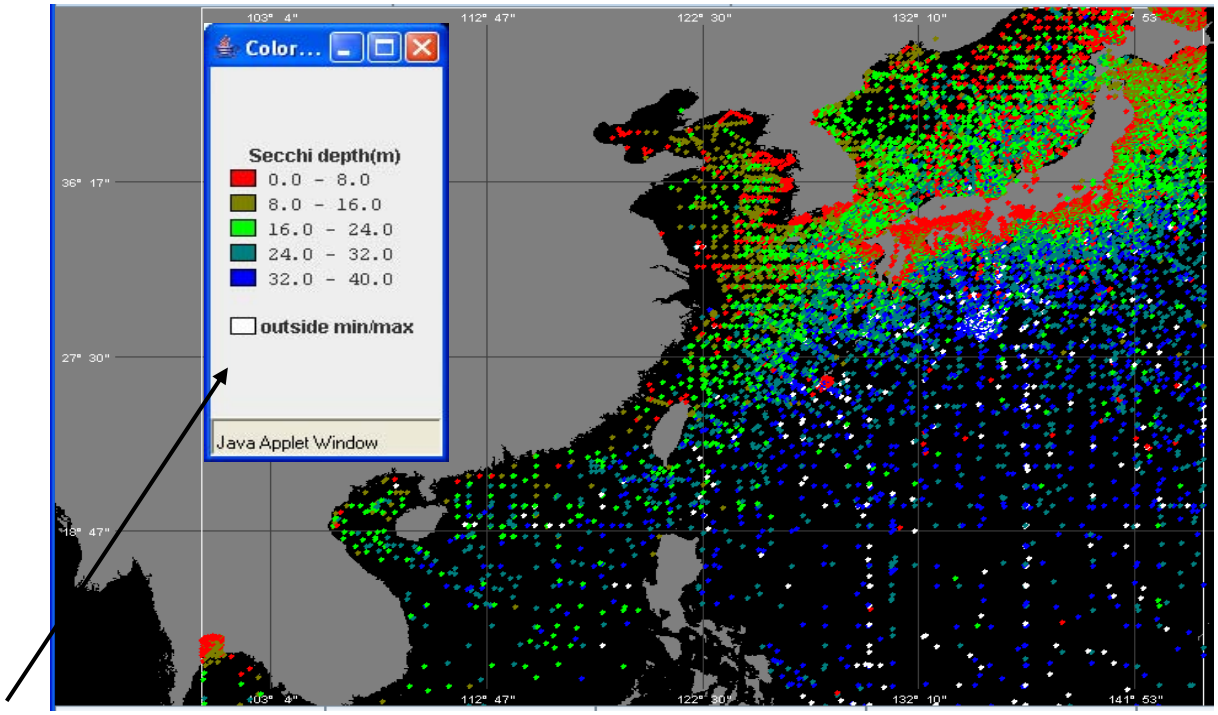
Table 1. Datasets Loaded into WOOD During GFY 06 (as of 30 August 2006)

Data Description	***Example Number & Types of Profiles***
NASA SeaBASS "Pigment" data	>1200 stations containing discrete depth measurements of (primarily) CHL_a, phaeophytin, & total pigments
SISMER[6] Med. Sea, Atl. Ocean near N. Africa, & Equatorial Pacific	> 5000 profiles of CHL_a, relative turbidity & relative fluorescence, dissolved oxygen, salinity, & temperature data
SISMER Mediterranean Sea & Equatorial Pacific Bottle Data	> 2000 stns of CHL_a, CHL_b, CHL_c, phaeophytin, relative turbidity & relative fluorescence, nutrients (O2, NO2, NO3, SiO4, NH4),salinity, & temperature data
H. Sosik (WHOI) SPMR & CTD Data from Gulf of Maine Cruise OC332, EN307,330, 331	476 profiles of Ed, Lu, Kd, KL versus wavelength and CTD profiles of temperature and salinity
WHOI ASIEX & Australia SeaSoar CTD + optics data	~ 2000 profiles of c660, KPAR, chlorophyll fluorescence, and CTD profiles of temperature and salinity
MBARI Equatorial Pacific SPMR	30 stations of Ed & Lu vs. wavelength

New Software Added to WOOD: The WOOD database connection is provided through a program called "Tomcat" using a Java servlet. On occasion this connection gets broken and needs to be restarted. An automated process has been added to the WOOD server that monitors the status of this connection and automatically sends an email to the Project Manager and to the Lead Software Engineer whenever this failure occurs. We are presently investigating a way to also automate the restart process.

New parameters (and corresponding new data) were also added, such as "K from PAR" (diffuse attenuation coefficient computed from photosynthetically-available radiation, or PAR), Yellow Matter fluorescence, and Total Suspended Particulate Matter (TSPM). A major improvement to the data display graphical user interface (GUI) was also added: the ability to show a color-coded depth slice of any parameter with a user-configurable color scale. An example for Secchi data collected in the northwestern Pacific Ocean is shown below in Figure 1.

While processing/adding new data to the database, we developed software that automatically processes NASA SeaBASS pigment files and SISMER data files. A summer student also wrote a powerful Matlab GUI that is used for on-screen spike editing and data review. A High School mentor student developed software that "thins" over-sampled, high density data such as those obtained by a SeaSoar tow-yo system or a glider. That software was successfully used on WHOI data from the South China Sea, the Australian coast, and the Arabian Sea. An example of applying the data thinning software to an over-sampled dataset is shown in Figure 2.



User-configured scale appears in a pop-up window

Figure 1. Summer Secchi depth data in the Western North Pacific Ocean. Regions of high turbidity (Secchi depths < 8 m) primarily occur in very shallow waters close to the coastline, and the clearest waters (Secchi depth > 32 m) generally occur in the deep waters further from shore.

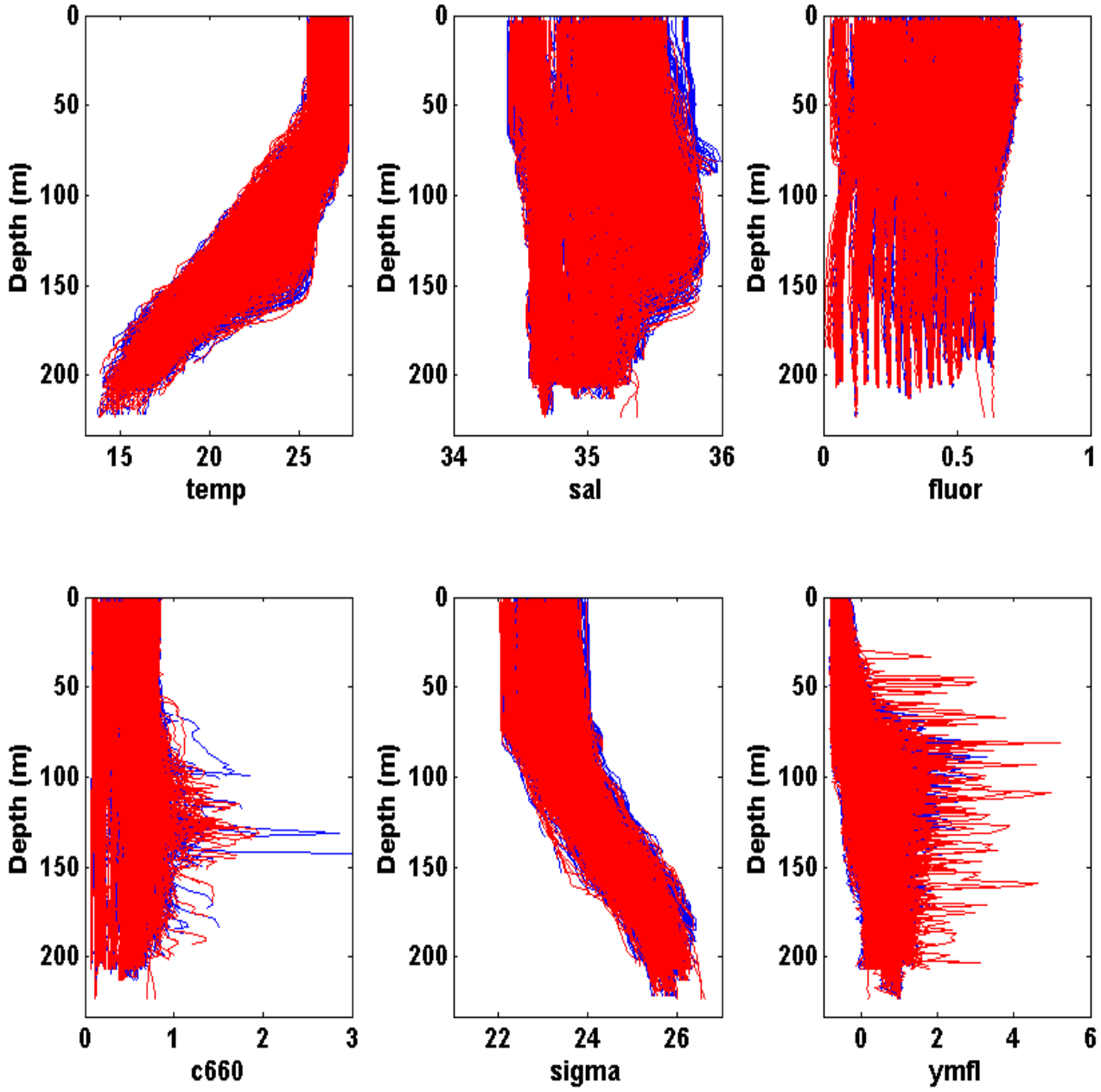


Figure 2. Example of Original (blue) and "Thinned" (red) Multi-Parameter Data Collected by the WHOI SeaSoar System off the Northwest Coast of Australia. The data thinning has reduced the number of profiles to approximately 25% of the original number while maintaining virtually all the structure seen in the original data. The parameters shown in this figure are (top row) temperature, salinity, relative fluorescence, (bottom row) beam c at 660 nm, SigmaT (computed form temperature and salinity), and Yellow Matter relative fluorescence. Note: the high-valued blue "outliers" between 50 and 150 m depth in the c660 profiles were individually examined and deemed to be spurious.

RESULTS

Many investigators from around the world make use of the WOOD. Figure 3shows a summary of the major increase in WOOD usage over the past several years. Over the period from July 2005 through July 2006, WOOD was accessed over 178,000 times by 15,049 different IP sites, which included 1,285 schools, colleges, universities, and research institutes, and 160 DoD/US Government/State-Local Government agencies. The 160 unique DoD/US Government -related "hits" included the agencies listed in Table 2.

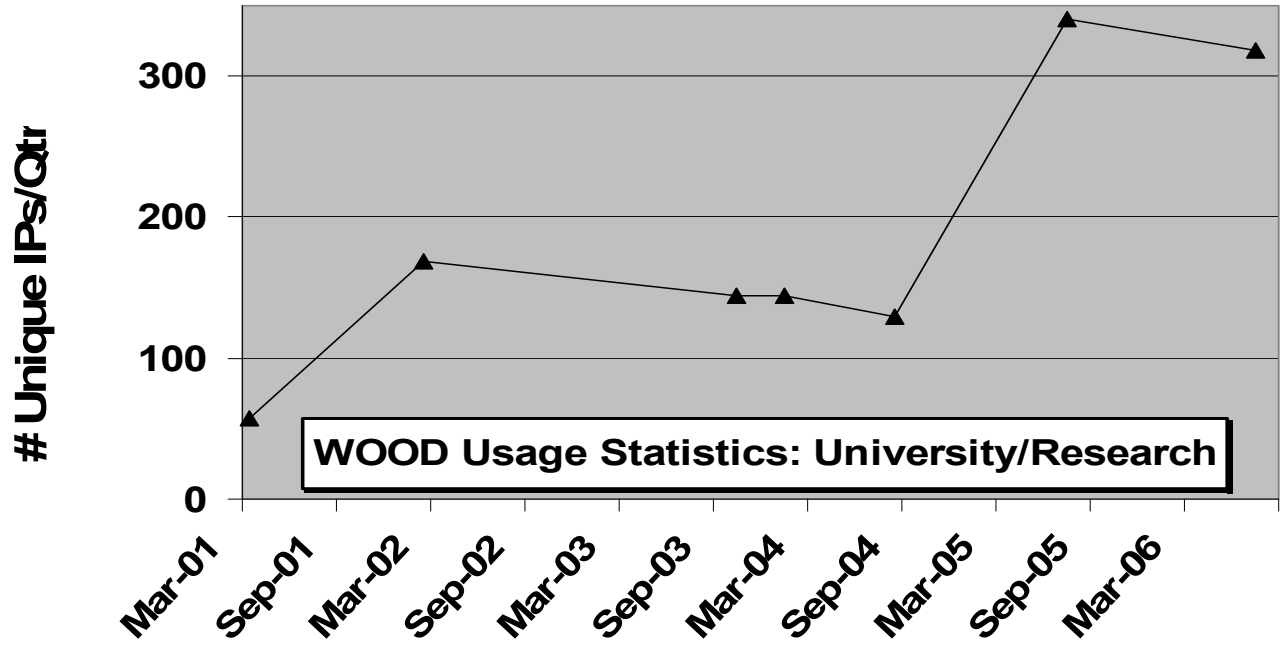


Figure 3 WOOD University/Research Usage Statistics from March 2001 to July 2006. [Unique IP address "hits" are reported and are normalized by the number of accesses per quarter. Less than 100 unique IP "hits" occurred until March 2002, the rate increased to 129 by August 2004, to 340 by July 2005, and was 320 in July 2006.]

As a specific example of US Navy use, the ONR Littoral Warfare Advanced Development (LWAD) Program used WOOD data extensively in planning for the LWAD 03-4 Sea Test in the East China Sea. In addition, the Environmental Support System for the SSBN Security Program used WOOD on two different assignments. WOOD has also been used to directly support our ONR sponsor, Dr. Steve Ackleson. For example, in 2005 he requested an analysis of the ~ 30,000 K profiles in WOOD that exist on the continental shelf in order to determine the fraction of the world's continental shelves that are sufficiently clear to allow a bottom-mounted sensor to measure downwelling radiance. A second sponsor request was to use WOOD to provide littoral multi-spectral beam attenuation coefficient profiles in areas having a nepheloid layer.

Table 2. Partial List of DoD/US Government -related "hits" to WOOD from July 2005 to July 2006

- Air Force Logistics Command
- Air Force Materiel Command
- Air Force Systems Command
- Air National Guard
- Andersen Air Force Base
- Center for Naval Analyses
- Defense Advanced Research Projects Agency
- Defense Technical Information Cntr
- Department of Veterans Affairs
- DoD Network Information Center
- Dover Air Force Base
- Federal Aviation Administration
- Headquarters, U.S. Army Recruiting Cmd
- HQ US Army Medical R& D Command
- Info. Systems, U.S. House of Representatives
- Institute for Defense Analyses
- Keesler Air Force Base
- Los Alamos National Laboratory
- National Aeronautics and Space Admin.
- National Center for Atmospheric Research
- National Institutes of Health
- National Oceanic and Atmospheric Admin.
- National Wetlands Research Center, USGS
- Naval Cmd Control & Ocean Surveil. Center
- Naval Postgraduate School
- Naval Research Laboratory (Stennis)
- National Center for Supercomputing
- National Climatic Data Center
- National Computer Security Center
- National Inst. of Standards and Technology
- National Institutes of Health
- National Oceanic and Atmospheric Admin.
- National Park Service
- National Renewable Energy Laboratory
- National Wetlands Research Center, USGS
- Naval Postgraduate School
- Naval Research Laboratory
- Naval Surface Warfare Center
- Naval Undersea Warfare Center
- Naval Undersea Warfare Cntr., Keyport
- Naval Undersea Warfare Engineering Stn
- Oak Ridge National Laboratory
- Office of the Chief of Naval Research
- Pearl Harbor Naval Shipyard
- Randolph Air Force Base
- Sandia National Laboratories
- U.S. CENTRAL COMMAND
- U.S. Dept. of Agriculture – ARS
- U.S. Dept. of Commerce – ITA
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- U.S. Army Corps of Engineers
- U.S. Army Space and Strategic Defense
- U.S. Department of Energy
- U.S. Department of State
- U.S. Department of Transportation
- U.S. Dept. of Commerce NOAA-NMFS
- U.S. Dept. of Health and Human Services
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- United States Naval Academy
- Wright-Patterson Air Force Base

IMPACT/APPLICATIONS

By requiring all projects funded by ONR's Ocean Optics Program to submit their data to the WOOD, ONR is ensuring that these valuable data continue to be available for current and future investigators. Furthermore, it is estimated that the availability of a single location, uniform-format optics database has saved the US Navy thousands of dollars in test planning and other naval applications. By providing the Navy and the research community with this resource, both types of users benefit from improved knowledge of the optical properties of the ocean. Access to historical optics data can also be useful for assessing newly acquired data. One can compare the two to see if the new results are atypical, and if so, one might go on to determine the cause (e.g. unusual forcing conditions, influx of a different water mass, or perhaps even an instrument calibration problem).

TRANSITIONS

Discussions have been initiated with Capt Kiser (CNMOC), R. Betsch (NAVOCEANO Mine Warfare Program Manger), and ONR to transition a classified version of WOOD to NAVOCEANO. We have sent a draft Technical Transfer Agreement (TTA) to ONR for review and are awaiting the availability of GFY07 funding to begin the TTA process. In prior years, a clone of WOOD, called FAST TACTIC, was developed and deployed as a prototype on two US Navy platforms. Some of the technology developed under that effort is expected to be included in the TTA. For related information at the unclassified level, see the Submarine Operational and Research Database (SOARED) website at http://wood.jhuapl.edu/soared/welcome.htm.

RELATED PROJECTS

The project's Principal Investigator, Jeff Smart, is a Project Manager and Lead Scientist on several classified projects that regularly use WOOD data to plan US Navy field tests and to conduct vulnerability studies. Mr. Smart is a also a member of the ONR Littoral Warfare Advanced Development (LWAD) project that conducts numerous at-sea tests, including tests involving optics in overseas areas of special interest to the US Navy. Via the LWAD project, the WOOD project has obtained important optical data in the East China Sea and the Yellow Sea. WOOD also provides LWAD with optics data for test planning purposes. The Applied Physics Laboratory is an official member of the NASA SeaWiFS Bio-optical Archive and Storage System (SeaBASS) community that has access to a proprietary bio-optics data. In order to obtain this privilege, US Navy permission was obtained to provide unclassified LWAD optics data (collected by JHU/APL scientists) to SeaBASS.

PUBLICATIONS

- "The Worldwide Ocean Optics Database (WOOD)--Ten Years Later," Ocean Optics XVIII, to be presented October 2006.

- "Underwater Optical Communications Systems. Part 1: Variability of Water Optical Parameters," invited written paper presented at MILCOM2005 (October 2005).

- "Assessing Optical Clarity in the Littorals," invited seminar presented at October 2005 Asymmetric Threats Conference, Silver Spring, Md.

REFERENCES

[1] WOOD Website: http://wood.jhuapl.edu

[2] SeaSoar Website: http://www.chelsea.co.uk/Vehicles%20SeaSoar.htm

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[4] MEDATLAS 2002 Website: http://www.ifremer.fr/sismer/program/medar/

[5] WHOI SeaSoar Website: http://science.whoi.edu/users/seasoar/

[6] SISMER Website: http://www.ifremer.fr/sismerData/jsp/donneesInSitu.jsp